08/11/00 JC803 U.S. PTO

A Reissue

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JC802 U.S. PTO 09/638796 08/11/00

August 11, 2000

BOX REISSUE
Assistant Commissioner for Patents
Washington, D.C. 20231

Re: Reissue Application of **Jae-moon JO and Je-Chang JEONG**
APAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA
Our Ref: **Q60197**

Dear Sir:

This is a request for filing a Reissue Application of U.S. Patent No. 5,793,897 issued on August 11, 1998 by Jae-moon JO and Je-Chang JEONG entitled APAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA. A Reissue Declaration and Power of Attorney will be submitted at a later date.

An Assent of Assignee to Reissue, Certificate Under 37 C.F.R. § 3.73(b) and Offer to Surrender Letters Patent will be submitted at a later date.

Please transfer the drawings from prior Application No. 08/495,591, on which U.S. Patent 5,793,897 issued, as there are no changes to the drawings. The specification, original patented claims, and original drawings are submitted in the form of a cut-up copy of U.S. Patent No. 5,793,897. Furthermore, new claims 8-17 are enclosed.

A PTO Form 1449 listing references, cited by applicants and/or the examiner during prosecution of the original application for U.S. Patent No. 5,793,897, is submitted herewith.

Priority is claimed from December 16, 1993 based on Korean Application No. 93-28074. The priority document was filed in parent Application No. 08/495,591, U.S. Patent No. 5,793,897.

The Government filing fee is calculated as follows:

Total claims	17	-	20	=	0	x	$18	=	$ 00.00
Independent claims	3	-	1	=	2	x	$78	=	$156.00
Base Fee									$690.00
TOTAL FILING FEE									**$846.00**

A check for the statutory fee of **$846.00** is attached. You are also directed and authorized to charge or credit any difference or overpayment to said account. The Commissioner is hereby authorized to charge any fees under 37 C.F.R. §§ 1.16 and 1.17 and any petitions for extension of time under 37 C.F.R. § 1.136 which may be required during the entire pendency of the application to Deposit Account No. 19-4880. A duplicate copy of this transmittal letter is attached.

Respectfully submitted,

SUGHRUE, MION, ZINN, MACPEAK
& SEAS, PLLC

Steven Franklin Reg # 36,818

for **Darryl Mexic**
Registration No. **23,063**

Q60197
PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Reissue Application of

Jae-moon JO and Je-Chang JEONG

Reissue Application of U.S. Patent
No. 5,793,897 issued on August 11, 1998

Filed: August 11, 2000 U.S. Appln. No. 09/638,796

For: **APAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA**

REISSUE DECLARATION UNDER 37 C.F.R. § 1.175

We, **Jae-moon JO**, of Kyungki-do, Republic of Korea and **Je-Chang JEONG**, of Seoul, Republic of Korea, do hereby declare and state as follows:

Our residence, post office address and citizenship are as stated below next to our names.

We believe that we are the original and first and joint inventors of the invention **APAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA** which is described and claimed in the above-identified U.S. Patent No. 5,793,897, issued August 11, 1998, and assigned to Samsung Electronics Co., Ltd., the specification of which is submitted with this application for reissue; and we affirm that we have reviewed and understand the contents of the specification, including the claims, as amended in this application for reissue.

In compliance with 37 C.F.R. § 1.175(a)(7) and 1.63(b)(3), we hereby acknowledge our duty to disclose information of which we are aware, which is material to patentability as defined in 37 C.F.R. § 1.56.

Priority is claimed under 35 U.S.C. § 119 from December 16, 1993 and December 15, 1994 based on Korean Patent Application Nos. 93-28074 and 94-34497, respectively.

In compliance with 37 C.F.R. §§ 1.175(a), we hereby declare and state that the above-identified U.S. Patent No. 5,793,897 is believed to be at least partly inoperative for the reason that we had claimed less than we had the right to claim in the patent.

REISSUE DECLARATION UNDER 37 C.F.R. § 1.175
REISSUE APPLICATION OF U.S. PATENT NO. 5,793,897

The purpose of seeking a reissue patent is to correct the insufficiency in the patented claims by presenting new claims that are commensurate with the true scope of our invention.

Pursuant to 37 C.F.R. § 1.175(a)(1), we state as follows at least one error in the patent, which is relied on as a basis for this reissue. Claim 1 of the '897 patent recites a step of "setting a plurality of variable-length coding tables having different patterns of a regular region and an escape region according to statistical characteristics of said run, level data." However, we believe that the language "having different patterns of a regular region and an escape region according to statistical characteristics of said run, level data" excessively limits the type of variable-length coding tables that can be set to perform the objects of the invention. Furthermore, claim 1 recites "wherein said selecting step has the selecting range of a plurality of variable-length coding tables having different patterns of a regular region and an escape region according to said intra/inter mode information of the currently processed block." However, we believe that the language "having different patterns of a regular region and an escape region according to said intra/inter mode information of the currently processed block" is excessively limiting. As such, we believe that new claims should be added that do not limit the types of variable-length coding tables that can be employed by this adaptive variable-length coding method.

The new independent claim 8 added in this reissue application does not include a recitation requiring the variable-length coding tables to be set "having different patterns of a regular region and an escape region according to statistical characteristics of said run, level data." Moreover, the new independent claim 8 does not include a recitation requiring the variable-length coding tables in the selecting range to have "different patterns of a regular region and an escape region according to said intra/inter mode information of the currently processed block." Accordingly, new independent claim 8 corrects an error in claiming less than we had a right to claim.

Pursuant to 37 C.F.R. § 1.175(a)(2), we state that all errors being corrected in the reissue application up to the time of filing this declaration arose without any deceptive intention.

We hereby appoint John H. Mion, Reg. No. 18,879; Thomas J. Macpeak, Reg. No. 19,292; Robert J. Seas, Jr., Reg. No. 21,092; Darryl Mexic, Reg. No. 23,063; Robert V. Sloan, Reg. No. 22,775; Peter D. Olexy, Reg. No. 24,513; J. Frank Osha, Reg. No. 24,625;

REISSUE DECLARATION UNDER 37 C.F.R. § 1.175
REISSUE APPLICATION OF U.S. PATENT NO. 5,793,897

Waddell A. Biggart, Reg. No. 24,861; Louis Gubinsky, Reg. No. 24,835; Neil B. Siegel, Reg. No. 25,200; David J. Cushing, Reg. No. 28,703; John R. Inge, Reg. No. 26,916; Joseph J. Ruch, Jr., Reg. No. 26,577; Sheldon I. Landsman, Reg. No. 25,430; Richard C. Turner, Reg. No. 29,710; Howard L. Bernstein, Reg. No. 25,665; Alan J. Kasper, Reg. No. 25,426; Kenneth J. Burchfiel, Reg. No. 31,333; Gordon Kit, Reg. No. 30,764; Susan J. Mack, Reg. No. 30,951; Frank L. Bernstein, Reg. No. 31,484; Mark Boland, Reg. No. 32,197; William H. Mandir, Reg. No. 32,156; Brian W. Hannon, Reg. No. 32,778; Abraham J. Rosner, Reg. No. 33,276; Bruce E. Kramer, Reg. No. 33,725; Paul F. Neils, Reg. No. 33,102; Brett S. Sylvester, Reg. No. 32,765; Robert M. Masters, Reg. No. 35,603, George F. Lehnigk, Reg. No. 36,359, John T. Callahan, Reg. No. 32,607 and Steven M. Gruskin, Reg. No. 36,818, our attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith, and request that all correspondence about the application be addressed to **SUGHRUE, MION, ZINN, MACPEAK & SEAS, PLLC**, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037-3213.

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this declaration is directed.

Date: 8/24/2000

First Inventor:

JAE	MOON	JO
First Name	Middle Initial	Last Name

Residence: SUWON CITY, KOREA

Signature: J. Moon

Post Office Address: SAMSUNG ELECTRONIC CO., 416, MAETAN-DONG PALDAL-KU, SUWON CITY, KOREA

Citizenship: KOREAN

REISSUE DECLARATION UNDER 37 C.F.R. § 1.175
REISSUE APPLICATION OF U.S. PATENT NO. 5,793,897

Date: 9/20/2000

Second Inventor:

Jechang		Jeong
First Name	Middle Initial	Last Name

Residence: SEOUL, KOREA

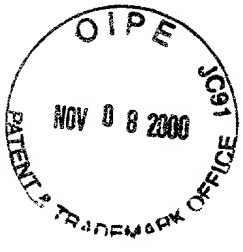
Signature: Jechang Jeong

Post Office Address: Department of Electronic Communication Engineering, Hanyang University, 17 Hangdang Sungdong, Seoul, KOREA

Citizenship: KOREAN

Q60197
PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE



In re Reissue Application of

Jae-moon JO and Je-Chang JEONG

Reissue Application of U.S. Patent
No. 5,793,897 issued on August 11, 1998

Filed: Herewith

For: **APAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA**

ASSENT OF ASSIGNEE TO REISSUE

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

Samsung Electronics Co., Ltd., the Assignee of the entire right, title and interest of the invention described and claimed in the above-identified U.S. Patent No. 5,793,897, hereby assents to the filing of the reissue application of said patent in accordance with the Reissue Declaration and accompanying papers submitted herewith. I aver that I am empowered to assent to the filing of the reissue application of said patent on behalf of Samsung Electronics Co., Ltd.

SAMSUNG ELECTRONICS CO., LTD.

Date: 2000. 8. 23

(Signature)

Hong Kuen Pyo
(Type Name)

Title: Senior Manager

OIPE
NOV 0 8 2000
PATENT & TRADEMARK OFFICE
JC91

Q60197
PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Reissue Application of

Jae-moon JO and Je-Chang JEONG

Reissue Application of U.S. Patent
No. 5,793,897 issued on August 11, 1998

Filed: Herewith

For: **APAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA**

OFFER TO SURRENDER LETTERS PATENT UNDER 37 C.F.R. § 1.178

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

Samsung Electronics Co., Ltd., is the Assignee of the entire right, title and interest of the invention described and claimed in the above-identified U.S. Patent No. 5,793,897. Samsung Electronics Co., Ltd., hereby offers to surrender U.S. Patent No. 5,793,897 to the U.S. Patent and Trademark Office (PTO).

A certificate under 37 C.F.R. § 3.73(b) is attached.

I am authorized to act on behalf of Samsung Electronics Co., Ltd.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this declaration is directed.

SAMSUNG ELECTRONICS CO., LTD.

Date: 2000. 8. 23.

Hong Kuen Pyo
(Signature)

Hong Kuen Pyo
(Type Name)

Title: Senior Manager

Q60197

PTO/SB/96

Approved for use through 8/30/98. OMB 0651-0027

Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1985, no persons are required to respond to a collection of information unless it displays a valid OMB control number

PATENT & TRADEMARK OFFICE NOV 0 8 2000 JC91

CERTIFICATE UNDER 37 C.F.R 3.73(b)

Applicant: Jae-moon JO and Je-Chang JEONG

Application No. U.S. Patent No. 5,793,897 Filed: Issued August 11, 1998

Entitled: APAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA

SAMSUNG ELECTRONICS CO., LTD. (Name of Assignee) , a Corporation (Type of Assignee, e.g., corporation , partnership, university, government agency, etc)

certifies that it is the assignee of the entire right, title and interest in the patent application identified above by virtue of either:

A. ☑ An assignment from the inventors of the patent application identified above. A copy which a copy thereof is attached.

From Jae-moon JO and Je-Chang JEONG To: Samsung Electronics Co., Ltd.

OR

B. ☐ A chain of title from the inventor(s), of the patent application identified above, to the current assignee as show below:

1. From _____ To: _____
The document was recorded in the Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.

2. From _____ To: _____
The document was recorded in the Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.

3. From _____ To: _____
The document was recorded in the Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet.

☐ Copies of assignments or other documents in the chain of title are attached.

The undersigned has reviewed all the documents in the chain of title of the patent application identified above and, tot he best of undersigned's knowledge and belief, title is in the assignee identified above.

The undersigned (whose title is supplied below) is empowered to sign this certificate on behalf of the assignee.

I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further, that these statements are made with the knowledge that willful false statements, and the like so made, are punishable b fine or imprisonment, or both, under Section 1001, Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

2000. 8. 23.
Date

Hong Kuen Pyo
Signature

Hong Kuen Pyo
Type or Printed Name

Senior Manager
Title

Burden Hour Statement: This form is estimated to take 0.5 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETE FORMS TO THIS ADDRESS. SEND TO Assistant Commissioner for Patents, Washington, DC 20231.

ASSIGNMENT

Whereas, I/We, **Jae-moon JO and Je-Chang JEONG** of **835-704, Hyundai Apt., Jangmi Maeul Yatap-dong, Bundang-gu, Seongnam-city Kyungki-do, 463-070 Republic of Korea and 108-1007, Wooseong Apt., Yangjae-dong Seocho-gu, Seoul 137-130 Republic of Korea**

hereinafter called assignor(s), have invented certain improvements in

ADAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA

and executed an application for Letters Patent of the United States of America therefor on

September 30, 1995; and

Whereas, **SAMSUNG ELECTRONICS CO., LTD.** of **416, Maetan-dong, Paldal-gu, Suwon-city, Kyungki-do, Republic of Korea** (assignee), desires to acquire the entire right, title and interest in the said application and invention, and to any United States patents to be obtained therefor;

Now therefore, for valuable consideration, receipt whereof is hereby acknowledged,

I/We the above-named assignor(s), hereby sell, assign and transfer to the above named assignee, its successors and assigns, the entire right, title and interest in the application and the invention disclosed therein for the United States of America, including the right to claim priority under 35 U.S.C. § 119, and I/we request the Commissioner of Patents to issue any Letters Patent granted upon the invention set forth in the application to the assignee, its successors and assigns; and I/we will execute without further consideration all papers deemed necessary by the assignee in connection with the United States application when called upon to do so by the assignee.

I/We hereby authorize and request my attorneys SUGHRUE, MION, ZINN, MACPEAK & SEAS of 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037-3202 to insert here in parentheses (Application number **08/495,591**, filed **August 2, 1995**) the filing date and application number of said application when known.

Date: September 30, 1995 s/ J. Moon
Jae-moon JO

Date: Sept. 30, 1995 s/ Jechang Jeong
Je-Chang JEONG

(Legalization not required but is prima facie evidence of execution under 35 U.S.C. §261)

8/92

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jc882 U.S. PTO
09/638796
08/11/00

August 11, 2000

BOX REISSUE
Assistant Commissioner for Patents
Washington, D.C. 20231

Re: Reissue Application of **Jae-moon JO and Je-Chang JEONG**
APAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA
Our Ref: **Q60197**

Dear Sir:

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An Assent of Assignee to Reissue, Certificate Under 37 C.F.R. § 3.73(b) and Offer to Surrender Letters Patent will be submitted at a later date.

Please transfer the drawings from prior Application No. 08/495,591, on which U.S. Patent 5,793,897 issued, as there are no changes to the drawings. The specification, original patented claims, and original drawings are submitted in the form of a cut-up copy of U.S. Patent No. 5,793,897. Furthermore, new claims 8-17 are enclosed.

A PTO Form 1449 listing references, cited by applicants and/or the examiner during prosecution of the original application for U.S. Patent No. 5,793,897, is submitted herewith.

Priority is claimed from December 16, 1993 based on Korean Application No. 93-28074. The priority document was filed in parent Application No. 08/495,591, U.S. Patent No. 5,793,897.

The Government filing fee is calculated as follows:

Total claims	17	-	20	=	0	x	$18	=	$ 00.00
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Base Fee									$690.00
TOTAL FILING FEE									**$846.00**

A check for the statutory fee of **$846.00** is attached. You are also directed and authorized to charge or credit any difference or overpayment to said account. The Commissioner is hereby authorized to charge any fees under 37 C.F.R. §§ 1.16 and 1.17 and any petitions for extension of time under 37 C.F.R. § 1.136 which may be required during the entire pendency of the application to Deposit Account No. 19-4880. A duplicate copy of this transmittal letter is attached.

Respectfully submitted,

SUGHRUE, MION, ZINN, MACPEAK
& SEAS, PLLC

Steven I. Weisburd Reg # 36,818
for **Darryl Mexic**
Registration No. **23,063**

US005793897A

United States Patent [19]

Jo et al.

[11] Patent Number: 5,793,897

[45] Date of Patent: Aug. 11, 1998

[54] **ADAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA**

[75] Inventors: **Jae-moon Jo**; **Je-Chang Jeong**, both of Seoul, Rep. of Korea

[73] Assignee: **Samsung Electronics Co., Ltd.**, Kyungki-do, Rep. of Korea

[21] Appl. No.: **495,591**

[22] PCT Filed: **Dec. 16, 1994**

[86] PCT No.: **PCT/KR94/00177**

§ 371 Date: **Nov. 3, 1995**

§ 102(e) Date: **Nov. 3, 1995**

[87] PCT Pub. No.: **WO95/17073**

PCT Pub. Date: **Jun. 22, 1995**

[30] **Foreign Application Priority Data**

Dec. 16, 1993 [KR] Rep. of Korea 93-28074
Dec. 15, 1994 [KR] Rep. of Korea 94-34497

[51] **Int. Cl.**[6] **G06K 9/00**

[52] **U.S. Cl.** **382/246**; 382/239

[58] **Field of Search** 382/232, 233, 382/235, 236, 238, 239, 244, 245, 246, 248, 250, 251, 252, 253, 240, 249, 270; 348/384, 390, 394, 395, 400, 401, 402, 403, 404, 405, 407, 431, 699; 358/426, 430, 432, 433, 261.1, 261.2, 261.3, 427; 386/81, 124

[56] **References Cited**

U.S. PATENT DOCUMENTS

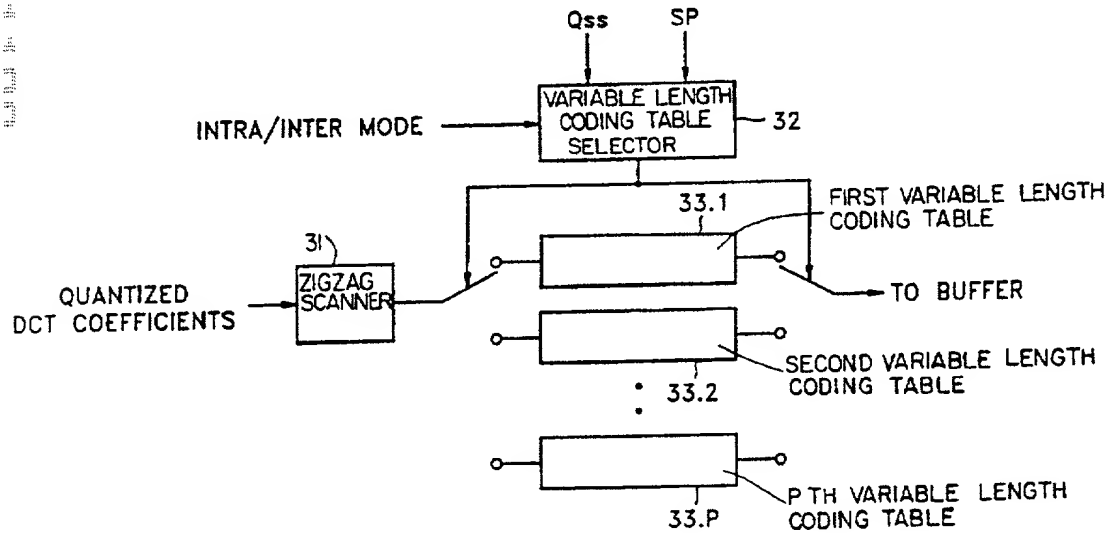
5,329,318 7/1994 Keith 348/699
5,377,051 12/1994 Lane et al. 360/33.1

Primary Examiner—Leo Boudreau
Assistant Examiner—Bijan Tadayon
Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas, PLLC

[57] **ABSTRACT**

An adaptive variable-length coding/decoding method performs an optimal variable-length coding and decoding depending on an intra mode/inter mode condition, quantization step size and a current zigzag scanning position, such that a plurality of variable-length coding tables having different patterns of a regular region and an escape region according to statistical characteristics of the run level data are set. One of the variable-length coding tables is selected according to mode, quantization step size and scanning position, and the orthogonal transform coefficients according to the selected variable-length coding table are variable-length-coded.

7 Claims, 7 Drawing Sheets



ADAPTIVE VARIABLE-LENGTH CODING AND DECODING METHODS FOR IMAGE DATA

TECHNICAL FIELD

The present invention relates to adaptive variablelength coding and decoding methods for digital image data, and more particularly, to adaptive variable-length coding and decoding methods which improve compression efficiency of transmission data by performing variable-length coding and decoding adaptively, according to statistical characteristics of image data.

BACKGROUND ART

Recently, in an apparatus for transmitting and receiving video and audio signals, a method by which the video and audio signals are coded to be digital signals to then be transmitted or stored in a memory and the digital signals are decoded to then be reproduced, has been widely adopted.

However, in the case of coding a video signal into digital data, the data quantity is large. Thus, in order to decrease the overall data quantity by removing redundant data contained in the digital video signal, discrete cosine transform (DCT) coding, differential pulse code modulation (DPCM), vector quantization, or variablelength coding (VLC) should be performed.

FIG. 1 is a schematic block diagram of a general coding system for image data. The apparatus includes means 11 and 12 for performing a DCT function with respect to an N×N block and for quantizing DCT coefficients, means 13 and 14 for variable-length-coding the quantized data and for further compressing data quantity, and means 15, 16, 17, 18, 19, A1, A2, SW1 and SW2 related to the inverse quantization and DCT operations with respect to the quantized data to then perform a motion compensation, which codes image data in an intra mode or inter mode.

FIG. 2 is a schematic block diagram of a general decoding system for image data. The apparatus decodes and reproduces the image data coded by the coding system shown in FIG. 1.

The operation of the coding and decoding systems respectively shown in FIGS. 1 and 2 will be briefly described.

In FIG. 1, the video signal input through an input port 10 becomes a signal of a frequency domain in the units of N×N blocks in DCT 11, where although the magnitude of a block is generally $N_1 \times N_2$, it is assumed that $N_1=N_2=N$, for the sake of convenience. The energy of transform coefficients is chiefly concentrated in a low frequency domain. Data transforms for each block are performed by a discrete cosine transform, Walsh-Hadamard transform, discrete Fourier transform, or discrete sine transform method. Here, the transform coefficients are obtained by DCT operation.

Quantizer 12 changes the DCT coefficients into representative values of a constant level through a predetermined quantization process.

Variable-length encoder 13 variable-length-codes the representative values using their statistical characteristics, thereby further compressing the data.

Meanwhile, a quantization step size Q_{ss}, which is varied depending on the state (a fullness) of a buffer 14 wherein the variable-length-coded data is stored, controls quantizer 12 to thereby adjust a transmission bit rate. The quantization step size Q_{ss} is also transmitted to a receiver side, to be used in a decoding system.

Also, in general, there are many similar portions between consecutive screens. Therefore, in the case of a screen

having motion, a motion vector MV is obtained by estimating the motion, and data is compensated using the motion vector MV. Then, a differential signal between adjacently positioned screens becomes very small, thereby allowing transmission data to be more compressed.

In order to perform such motion compensation, an inverse quantizer (Q^{-1}) **15** shown in FIG. **1** inverse-quantizes the quantized data output from quantizer **12**. Thereafter, the inverse-quantized data is inverse-DCT-operated in an inverse DCT means (DCT^{-1}) **16** to then be a video signal of a spatial domain. The video signal output from inverse DCT means **16** is stored in a frame memory **17** in frame units. Motion estimator **18** searches a block having the most similar pattern to that of an N×N block of input port **10** among the frame data stored in frame memory **17** and estimates the motion between blocks to obtain a motion vector MV. The motion vector MV is transmitted to a receiver side to be used in a decoding system and is simultaneously transmitted to a motion compensator **19**.

Motion compensator **19** receives the motion vector MV from motion estimator **18** and reads out an N×N block corresponding to the motion vector MV from the previous frame data output from frame memory **17** to then supply the read N×N block to a subtractor A1 connected with input port **10**. Then, subtractor A1 obtains the difference between the N×N block supplied to input port **10** and the N×N block having the similar pattern thereto supplied from motion compensator **19**. The output data of subtractor A1 is coded and then transmitted to the receiver side, as described above. That is to say, initially, the video signal of one screen (intraframe) is coded wholly to then be transmitted. For the video signal of the following screen (interframe), only the differential signal due to the motion is coded to then be transmitted.

Meanwhile, the data whose motion is compensated in motion compensator **19** is summed with the video signal output from inverse DCT means **16** in an adder A2 and is thereafter stored in frame memory **17**.

Refresh switches SW1 and SW2 are turned off at a certain interval (here, the period is one group of pictures or a GOP period) by a control means (not shown), so that an input video signal is coded into a PCM mode to then be transmitted in the case of an intraframe mode and so that only the differential signal is coded to then be transmitted in the case of an interframe mode, thereby refreshing cumulative coding errors for a constant period (one GOP). Also, a refresh switch SW3 allows the transmission errors on a channel to deviate from the receiver side within the constant time period (one GOP).

In this manner, the coded image data V_c is transmitted to the receiver side to then be input to the decoding system shown in FIG. **2**. The coded image data Vc is decoded through the reverse process to the coding process in a variable-length decoder **21**. The data output from variable-length decoder **21** is inverse-quantized in an inverse quantizer **22**. At this time, inverse quantizer **22** adjusts the magnitude of the output DCT coefficients depending on the quantization step size Q_z, supplied from the encoding system.

An inverse DCT means **23** inverse-DCT-operates the DCT coefficients of a frequency domain, supplied from inverse quantizer **22**, into the image data of a spatial domain.

Also, the motion vector MV transmitted from coding system shown in FIG. **1** is supplied to a motion compensator **24** of decoding system. Motion compensator **24** reads out the N×N block corresponding to the motion vector MV from the

previous frame data stored in a frame memory 25, compensates the motion and then supplies the compensated N×N block to an adder A3. Then, adder A3 adds the inverse-DCT-operated DPCM data to the N×N block data supplied from motion compensator 24 to then output to a display.

FIGS. 3A, 3B and 3C schematically show the process of coding image data. The sampling data of an N×N block shown in FIG. 3A is DCT-operated to be DCT coefficients of a frequency domain by the DCT method, etc., as shown in FIG. 3B. The DCT coefficients are quantized and are scanned in a zigzag pattern, to then be coded in the form of runlength and level-length, as shown in FIG. 3C.

While the scanning is performed from a low frequency component to a high frequency component in scanning the N×N block, as shown in FIG. 3C, a "run" and "level" and set as a pair expressed as [run, level], and is then coded.

Here, the run represents the number of 0's present between coefficients not being "0" among the quantized coefficients of an N×N block, and the level corresponds to the absolute value of the coefficient not being "0".

For example, in the case of an 8×8 block, the run is distributed from "0" to "63" and the level varies depending to the data value output from a quantizer. That is to say, if the quantized output value is indicated as an integer ranging from "−255" to "+255," the level has a value ranging from "1" to "+255." At this time, the positive or negative sign is expressed by an extra sign bit. In this manner, when a [run, level] pair is set as a symbol, if the run or level is large, the probability of the symbol is statistically very low.

Therefore, as shown in FIG. 4, the block is divided into a regular region and an escape region according to the probability of the symbol. For the regular region where the probability of the symbol is relatively high, a Huffman code is used in coding. For the escape region where the probability of the symbol is low, data of a predetermined fixed length is used in coding. Here, according to the Huffman code, the higher the probability of the symbol, the shorter the code is set, and vice versa.

Also, the escape sequence ESQ in which data of escape region is coded is composed of an escape code ESC, run, level and sign data S, each having a predetermined number of bits, as expressed in the following equation (1).

$$ESQ=ESC+RUN+L+S \quad (1)$$

For example, as described above, if the quantized value is from "−255" to "+255" in an 8×8 block, the escape sequence has a constant data length of 21 bits in total since the escape code data ESC is six bits, run data RUN is six bits, level data L is eight bits, and sign data S is one bit.

In this manner, according to the conventional variable-length coding method, since various extra information is also transmitted together with coded data and the escape sequence set by one variable-length coding table depending on the statistical characteristics of data has a constant fixed length, there is a limit in compressing data quantity by coding transmitted data.

Disclosure of the Invention

Therefore, it is an object of the present invention to provide an adaptive variable-length coding method which improves compression efficiency of data by selecting an optimal variable-length coding table among a plurality of variable-length coding tables according to the current scanning position and quantization step size while scanning in a zigzag pattern by block type, i.e., inter/intra mode.

It is another object of the present invention to provide a method for decoding data coded by the above adaptive variable-length coding method.

To accomplish the above object, there is provided an adaptive variable-length coding method according to the present invention whereby quantized orthogonal transform coefficients are scanned in a zigzag pattern, are DCT-operated to be [run, level] data and then are variable-length-coded in a coding system for image data, the method comprising the steps of:

setting a plurality of variable-length coding tables having different patterns of a regular region and an escape region according to statistical characteristics of the [run, level] data;

selecting one of the plurality of variable-length coding tables according to intra/inter mode information of the currently processed block, zigzag scanning position and quantization step size; and

variable-length-coding the orthogonal transform coefficients according to the selected variable-length coding table.

In a decoding system for image data, the adaptive variable-length decoding method according to the present invention for decoding data coded by the adaptive variable-length coding method, comprises the steps of:

setting a plurality of variable-length decoding tables having different patterns of a regular region and an escape region according to statistical characteristics of the [run, level] data;

inputting intra/inter mode information transmitted from the coding system;

inputting quantization step size transmitted from the coding system;

detecting position information while zigzag-scanning by accumulating run values of [run, level] data;

selecting one of the plurality of variable-length decoding tables according to the intra/inter mode information, quantization step size and position information; and

variable-length-decoding the data received according to the selected variable-length decoding table.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a general coding system for image data;

FIG. 2 is a block diagram of a general decoding system for image data;

FIGS. 3A–3C are schematic diagrams for explaining steps of the data processing process according to the apparatus shown in FIG. 1;

FIG. 4 shows a conventional variable-length coding and decoding table;

FIG. 5 is a schematic block diagram of a variable-length encoder for implementing an adaptive variable-length coding method according to the present invention;

FIGS. 6A and 6B illustrate a method for selecting a variable-length coding table partitioned by a predetermined number in the adaptive variable-length coding method according to the present invention, wherein FIG. 6A represents the intra mode and FIG. 6B represents the inter mode; and

FIGS. 7A, 7B and 7C are histograms [run, level] for each symbol at the first, second and Pth regions shown in FIGS. 6A and 6B.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinbelow, a preferred embodiment of the present invention will be described with reference to the accompanying drawings.

In the adaptive variable-length coding method according to the present invention, a plurality of variable-length coding tables are used. The table is selected in accordance with a block type, quantization step size and a current scanning position while scanning a block in a zigzag pattern. This selection is in accordance with the statistical characteristics of |run, level| data which vary depending on block type, i.e., intra mode/inter mode or luminance signal/color signal, quantization step size and a current zigzag scanning position, and which will be described in more detail.

The inter mode for coding the differential signal between the current block data and motion compensated block data generates most of the DCT coefficients as "0" but scarcely generates larger values, compared to the intra mode for coding input block image data sequentially. This is because the variation in a motion compensation estate error thereof is typically smaller than that of the original video signal.

Also, the statistical characteristics of color which depend on the decimation in the spatial domain and narrow bandwidth are different from those of luminance.

Therefore, in accordance with intra/inter mode and luminance/color information, there may be four block types, i.e., (intra, luminance), (intra, color), (inter, luminance) and (inter, color). However, for the block type in the present invention, the luminance/color information is excluded and only the intra/inter mode is considered, because the color statistics are dependent on the downsampling structure of the color signal.

Also, in the case of a large quantization step size, DCT coefficients are not high in the high frequency components and many are generated as "0's" while the quantizer scans in a zigzag pattern. That is to say, in order to utilize the human visual characteristics, the DCT coefficients are divided into primary weighting matrices. Since the weighting matrix for high frequency component is large, when the current scanning is a high frequency component, small values (including "0") are often produced but large values are scarcely generated.

Therefore, the present invention proposes an adaptive variable-length coding/decoding method using a plurality of variable-length coding/decoding tables in which the block type (intra/inter mode), scanning position and quantization step size are combined, which is called a Huffman code book.

Also, the present invention is adopted for a general coding system shown in FIG. 1 and for a general decoding system shown in FIG. 2.

FIG. 5 is a schematic block diagram of a variable-length encoder for implementing the adaptive variable-length coding method according to the present invention.

According to FIG. 5, quantized DCT coefficients are scanned in a zigzag pattern by zigzag scanner 31.

Variable-length coding table selector 32 outputs a control signal for selecting the corresponding first to Pth variable-length coding tables 33.1, 33.2, . . . , 33.P according to the block type (intra/inter mode), quantization step size Qss, and scanning position SP.

The quantized DCT coefficients output from zigzag scanner 31 are variable-length-coded in accordance with the selected variable-length coding table, to then be transmitted to buffer 14 shown in FIG. 1.

Variable-length decoder 21 of the decoding system shown in FIG. 2 variable-length-decodes data coded in the reverse order to that of the variable-length coding process as shown in FIG. 5.

Subsequently, the method for selecting a plurality of variable-length coding/decoding tables will be described in detail with reference to FIGS. 6A, 6B and 7A to 7C.

FIG. 6A shows P variable-length coding tables T_1, T_2, ... T_p selected in accordance with quantization step size Q_{ss} and the current scanning position SP (during zigzag scanning) for the intra mode. FIG. 6B shows P variable-length coding tables T_1, T_2, ... T_p selected in accordance with quantization step size Q_{ss} and the current scanning position SP (during zigzag scanning) for the inter mode.

The "0" scanning position SP corresponds to the DC component, the "63" scanning position SP represents the last scanning position in the corresponding block, and quantization step size Q_{ss} has values ranging from "0" to "62."

First, in order to select one of P variable-length coding tables T_1, T_2, ... T_p, it is determined whether the currently process block mode is an inter mode or intra mode.

That is to say, as shown in FIGS. 6A and 6B, the blocks for selecting the variable-length coding tables T_1, T_2, ... T_p are different depending on the mode. In other words, compared to the inter mode, the intra mode has larger selection blocks for the first and second variable-length coding tables T_1 and T_2 and a smaller selection block for the Pth variable-length coding table T_p.

In the determined mode, the first, second or Pth variable-length coding table T_1, T_2 or T_p are selected in accordance with quantization step size Q_{ss} and scanning position SP.

Quantized DCT coefficients are variable-length-coded in accordance with the selected variable-length coding table.

Here, an example of P regions partitioned on a (SP, Q_{ss}) plane in accordance with intra and inter modes shown in FIGS. 6A and 6B can be expressed as follows.

In the intra mode:

region 1: $SP+Q_{ss}<K_1$;

region 2: $K_1 \leqq SP+Q_{ss}<K_2$; and

region P: $K_p-1 \leqq SP+Q_{ss}<K_p$In the inter mode:

region 1: $SP+Q_{ss}<L_1$;

region 2: $L_1 \leqq SP+Q_{ss}<L_2$; and

region P: $L_p-1 \leqq SP+Q_{ss}<L_p$

The proper partition as above can be sought empirically based on sufficient statistical analysis for various experimental states. These states include such factors as video sequence, bit rate, GOP and partitioning method.

FIGS. 7A, 7B and 7C show examples of the variable-length coding tables shown in FIGS. 6A and 6B.

The variable-length coding tables have a regular region and escape region which differ depending on the statistical characteristics of [run, level].

That is to say, the first, second, ... Pth tables T_1, T_2, . . . T_p have the regular region and escape region having different patterns and the Pth table T_p has a smaller regular region than that of the first or second tables T_1 or T_2.

Meanwhile, the [run, level] symbol is likely to have a low probability thereof if the run and/or level lengths have a large value. As shown in FIG. 4, the respective symbols of the escape region has a fixed length of 21 bits obtained by adding a six-bit escape code, an eight-bit run, one-bit sign data.

However, in escape coding, since there is redundancy in the run and level fields, the data quantity may be reduced. That is to say, the bit number required for expressing run is dependent on the scanning position during zigzag scanning for two dimensional DCT coefficients and the bit number required for expressing level is dependent on the quantization step size. Also, quantization weighting matrices of intra-coded blocks and inter-coded blocks are different from each other.

The new escape sequence ESQ having a fixed length of 21 bits can be modified into that having a variable length using the aforementioned characteristics according to Equation (1) above, where ESQ is composed of six bits, RUN is com-

posed of zero to six bits, L is composed of one to eight bits, S is composed of one bit, the run data is dependent upon scanning position, and the level is dependent upon quantizer.

Therefore, since the modified escape sequence has a variable length ranging from eight to 21 bits, compared to the fixed length of 21 bits, image data can be further compressed.

In decoding the new escape sequence, since the respective current scanning positions are automatically matched for the coding system and decoding system, the number of bits required for expressing the run value can be matched without transmitting extra information. Also, in the case of the level length, since the quantization step size is transmitted to the decoding system for inverse quantization, the transmitted quantization step size can be used in synchronizing the number of bits required for expressing level, which requires no extra information to be transmitted.

The above-described variable-length coding and decoding methods which improve compression efficiency by adjusting the length of the escape sequence variably are disclosed in the U.S. pat. application Ser. No. 08/069,914 filed on Jun. 1, 1993 by the assignee of the present invention.

According to the present invention, a plurality of variable-length tables are provided for both the coding and decoding sides, which may be slightly more complex in hardware, compared to the case of using a conventional single table. However, the present invention is adopted for the case when a high data compression rate is necessary. Also, the corresponding mode, quantization step size and scanning position information generated in coding side is transmitted to the decoding side. The mode and quantization step size information is transmitted in a constant period of time or is transmitted whenever there is a change. The scanning position information is not transmitted separately but is obtained automatically by accumulating the run values after obtaining [run, level] values of the decoding side.

Therefore, although the information on the selected variable-length coding table is not transmitted separately with respect to the block data transmitted to the decoding side, the variable-length coding table selected during coding can be identified from the mode and quantization step size information transmitted from the coding side and the position information automatically calculated from the run value in the decoding side. Then, the same variable-length coding table as that adopted for coding is used for decoding the transmitted block data.

As described above, the method according to the present invention can increase data compression efficiency such that image data coded and decoded by selecting one of a plurality of variable-length coding tables having a regular region and an escape region, using mode, quantization step size and zigzag scanning position information.

Also, according to the present invention, no extra bit which expresses the variable-length coding table selected during coding is necessary to be transmitted for decoding. The transmission data can be further compressed by adjusting variably the run and level lengths of the data to be coded in the escape region of the selected variable-length coding table.

Industrial Applicability

An adaptive variable-length coding/decoding method according to the present invention can improve the compression efficiency of digitally transmitted data and is applicable to various technological fields including digital communication, multimedia and personal computer systems, and digital video apparatuses such as a high definition television or digital videocassette recorder.

What is claimed is:

1. An adaptive variable-length coding method whereby quantized orthogonal transform coefficients are scanned in a

zigzag pattern, are modified into run, level data and then are variable-length coded in a coding system for image data, said method comprising the steps of:

setting a plurality of variable-length coding tables having different patterns of a regular region and an escape region according to statistical characteristics of said run, level data;

selecting one of said plurality of variable-length coding tables according to intra/inter mode information of the currently processed block, zigzag scanning position and quantization step size; and

variable-length coding the orthogonal transform coefficients according to said selected variable-length coding table, wherein said selecting step has the selecting range of a plurality of variable-length coding tables having different patterns of a regular region and an escape region according to said intra/inter mode information of the currently Processed block.

2. The adaptive variable-length coding method as claimed in claim 1, wherein said variable-length coding table is selected in accordance with said zigzag scanning position and quantization step size within the range determined by the corresponding mode.

3. The adaptive variable-length coding method as claimed in claim 1, wherein data of said escape region of said variable-length coding table selected in said variable-length-coding step is coded into data having variable run-length and level-length.

4. An adaptive variable-length decoding method for decoding the data coded by said adaptive variable-length coding method as claimed in claim 1, in a decoding system for image data, said decoding method comprises the steps of:

setting a plurality of variable-length decoding tables having different patterns of a regular region and an escape region according to statistical characteristics of the run, level data;

inputting intra/inter mode information transmitted from said coding system;

inputting quantization step size transmitted from said coding system;

detecting position information while zigzag-scanning by accumulating run values of run, level data;

selecting one of said plurality of variable-length coding tables according to said intra/inter mode information, quantization step size and position information; and

variable-length decoding the data received according to said selected variable-length coding table.

5. The adaptive variable-length decoding method as claimed in claim 4, wherein said variable-length decoding table selecting step has the selection range of a plurality of variable-length coding tables having different patterns of a regular region and an escape region according to said intra/inter mode information of the currently processed block in said mode information inputting step.

6. The adaptive variable-length decoding method as claimed in claim 5, wherein said variable-length decoding table is selected in accordance with said zigzag scanning position and quantization step size within the range determined by the corresponding mode.

7. The adaptive variable-length decoding method as claimed in claim 4, wherein data of said escape region of said variable-length decoding table selected in said variable-length-decoding step is decoded into run, level data corresponding to variable run-length and level-length.

* * * * *

8. An adaptive variable-length coding method in which quantized orthogonal transform coefficients are scanned in a predetermined pattern, and then are variable-length coded in a coding system for image data, said method comprising the steps of:

setting a plurality of variable-length coding tables;

selecting one of said plurality of variable-length coding tables according to intra/inter mode information, and scanning position and quantization step size, wherein said selecting step has the selecting range of a plurality of variable-length coding tables; and

variable-length coding said quantized orthogonal transform coefficients according to said selected variable-length coding table.

9. The adaptive variable-length coding method of claim 8, wherein said variable-length coding tables have different patterns of a regular region and an escape region.

10. The adaptive variable-length coding method as claimed in claim 9, wherein said variable-length coding table is selected in accordance with said scanning position and quantization step size within the range determined in accordance with said intra/inter mode information.

11. The adaptive variable-length coding method as claimed in claim 9, wherein data of said escape region of said variable-length coding table selected in said variable-length-coding step is coded into data having variable run-length and level-length.

12. An adaptive variable-length decoding method for decoding the data coded by an adaptive variable-length coding method, in a decoding system for image data, said decoding method comprising the steps of:

receiving intra/inter mode information;

receiving quantization step size;

detecting position information;

selecting one of a plurality of variable-length decoding tables according to said intra/inter mode information, quantization step size and position information; and

variable-length decoding the data received according to said selected variable-length coding table.

13. The adaptive variable-length decoding method of claim 12, wherein said detecting position information step is performed by in accordance with run, level data.

14. The adaptive variable-length decoding method as claimed in claim 13, wherein said variable-length decoding table selecting step has the selection range of a plurality of variable-length decoding tables having different patterns of a regular region and an escape region according to said intra/inter mode information of the currently processed block in said mode information inputting step.

15. The adaptive variable-length decoding method as claimed in claim 14, wherein said variable-length decoding table is selected in accordance with said zigzag scanning position and quantization step size within the range determined in accordance with said intra/inter mode information.

16. The adaptive variable-length decoding method as claimed in claim 15, wherein data of said escape region of said variable-length decoding table selected in said variable-length decoding step is decoded into run, level data corresponding to variable run-length and level-length.

17. The adaptive variable-length decoding method of claim 16, wherein said detecting position information step is performed by accumulating the number positions indicated by a run value and level data.

FIG. 1

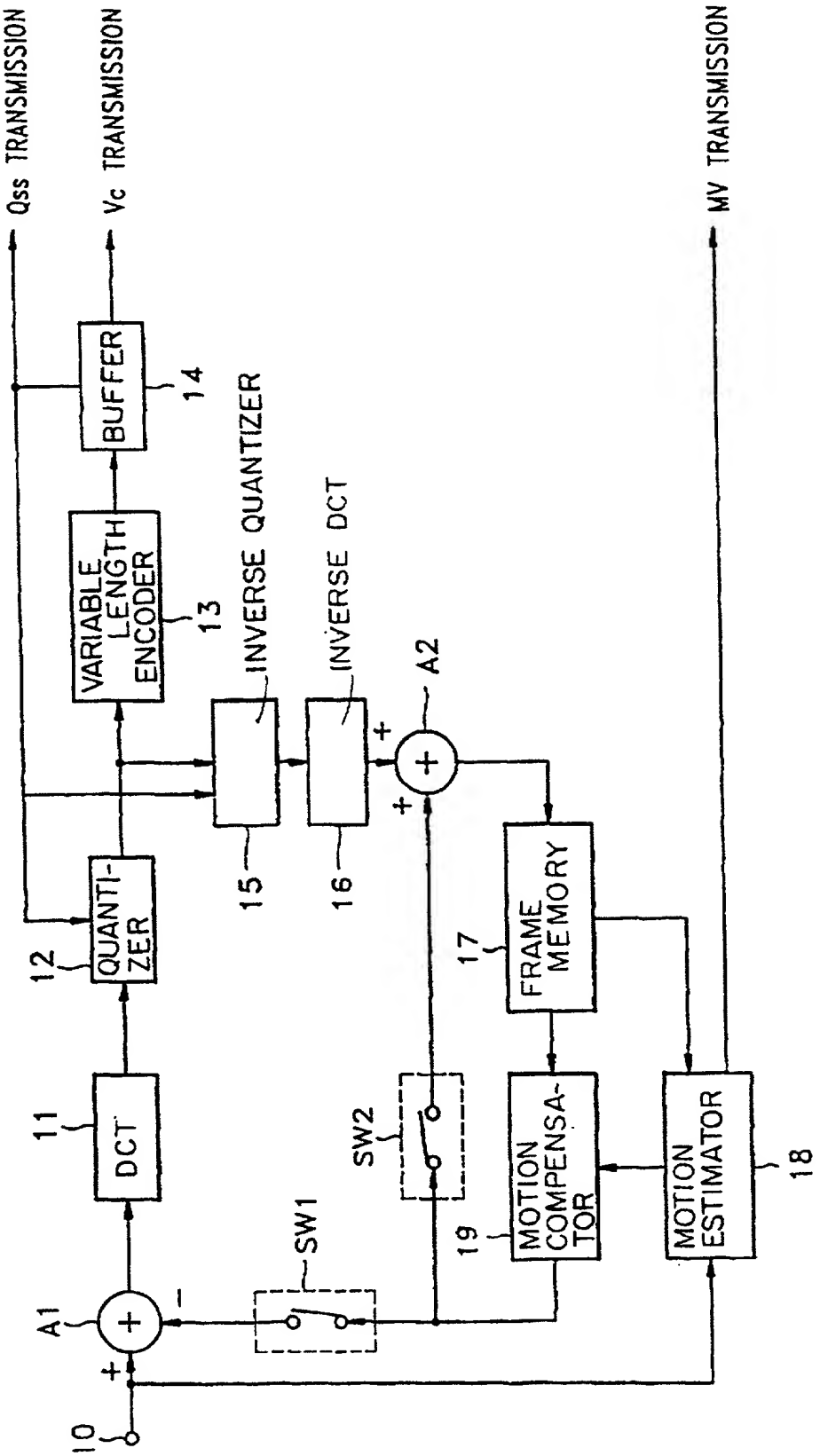

Qss TRANSMISSION
Vc TRANSMISSION
MV TRANSMISSION
BUFFER
14
VARIABLE LENGTH ENCODER
13
INVERSE QUANTIZER
INVERSE DCT
A2
15
16
QUANTI-ZER
12
FRAME MEMORY
17
DCT
11
SW2
SW1
MOTION COMPENSA-TOR
19
MOTION ESTIMATOR
18
A1
10

FIG. 2

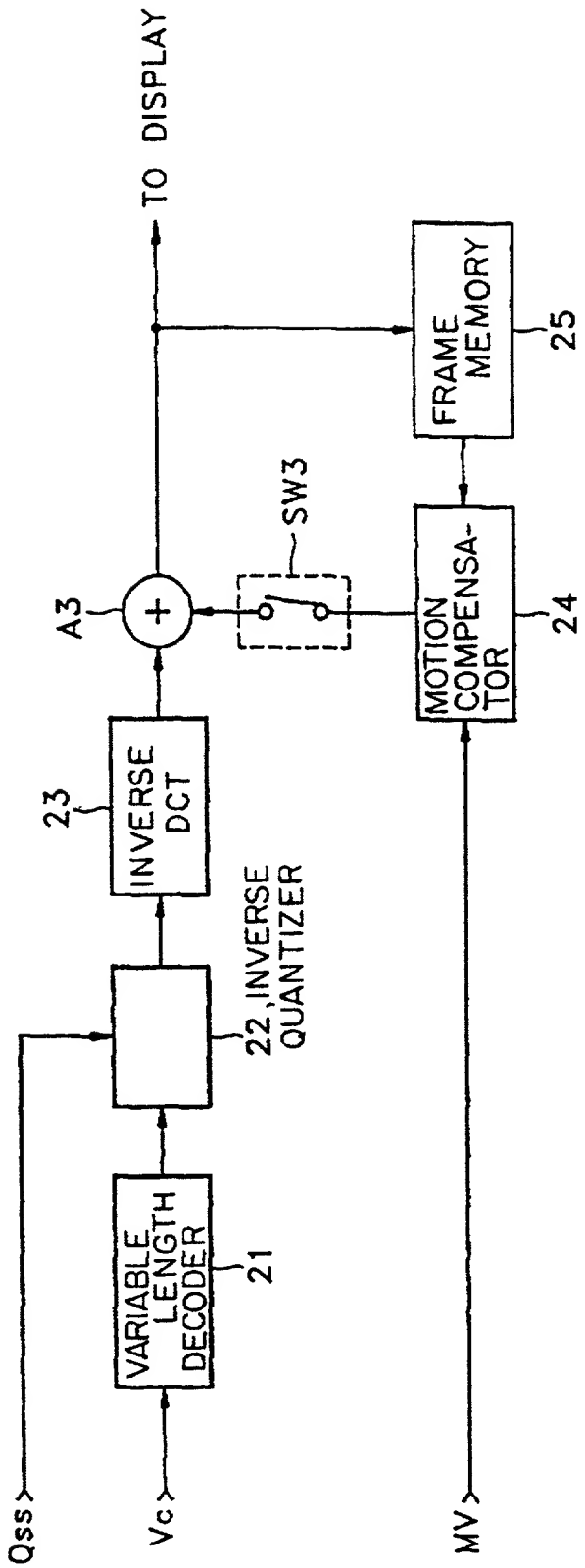

TO DISPLAY
FRAME MEMORY
25
SW3
A3
MOTION COMPENSA-TOR
24
23
INVERSE DCT
22, INVERSE QUANTIZER
VARIABLE LENGTH DECODER
21
Qss
Vc
MV

FIG. 3C

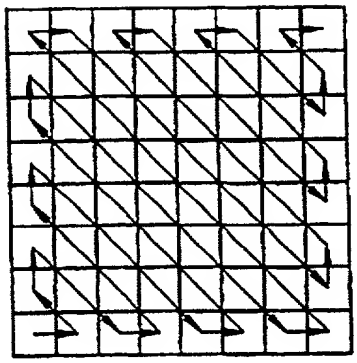


FIG. 3B

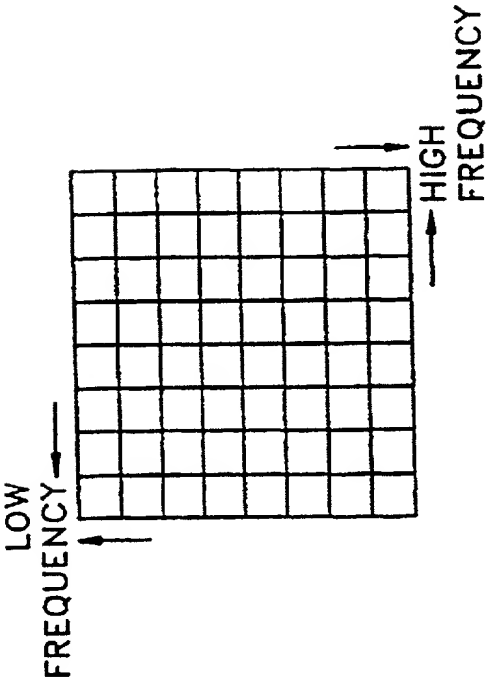


FIG. 3A

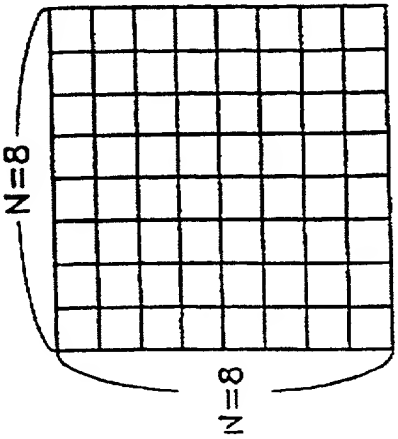


FIG. 4

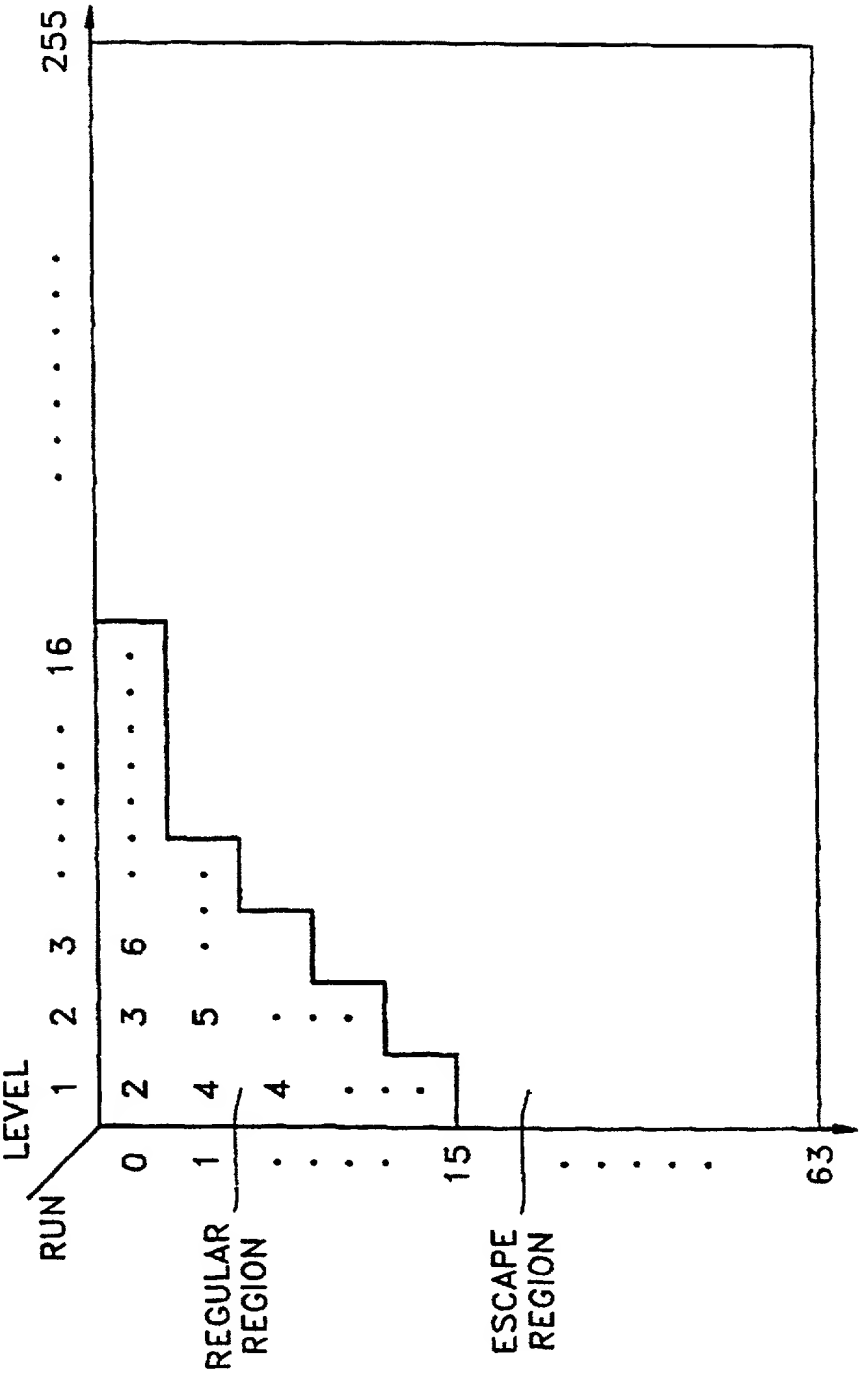

255
16
3
2
1
LEVEL
2
3
6
2
4
5
4
0
1
15
63
RUN
REGULAR REGION
ESCAPE REGION

FIG. 5

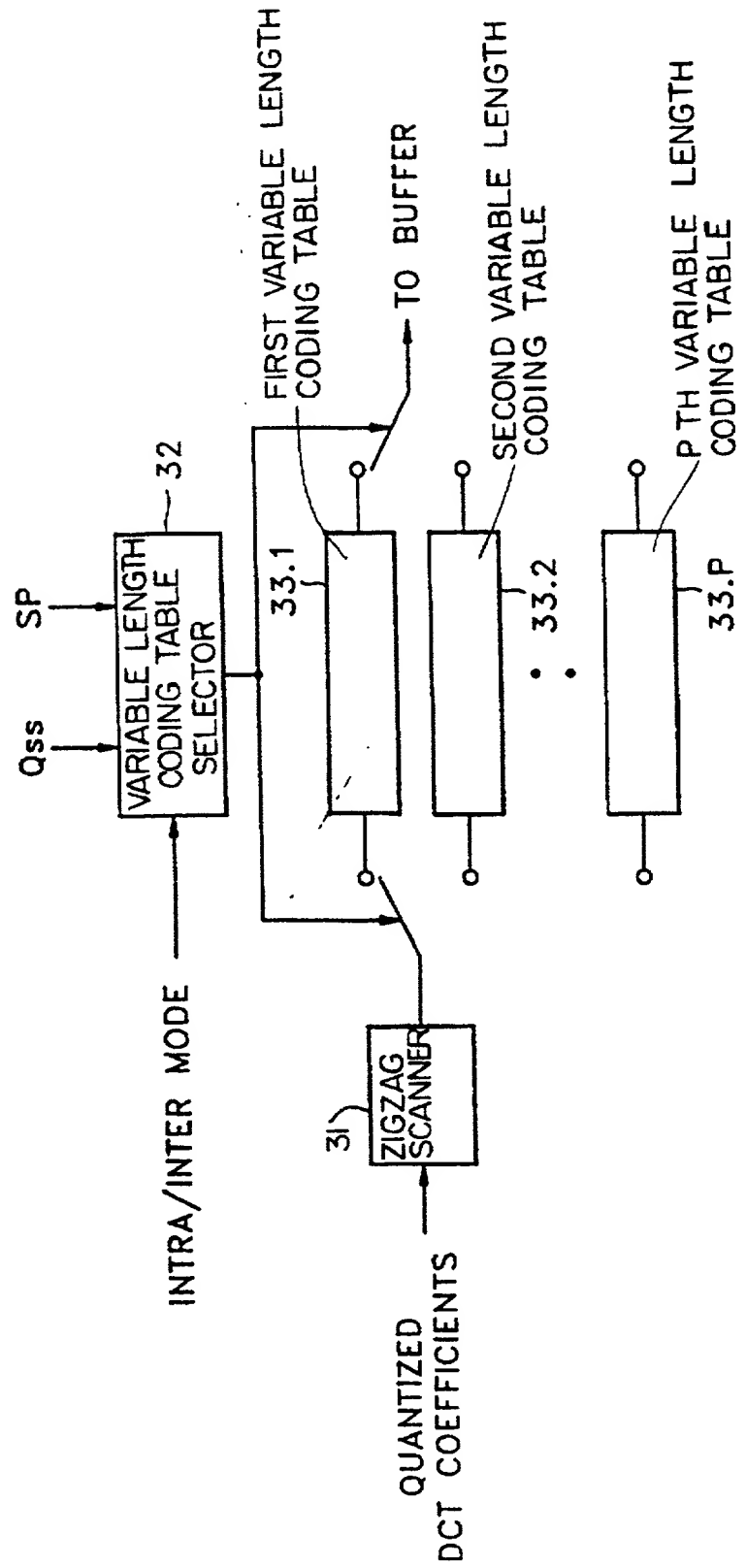

SP
Qss
VARIABLE LENGTH CODING TABLE SELECTOR
32
INTRA/INTER MODE
FIRST VARIABLE LENGTH CODING TABLE
33.1
TO BUFFER
SECOND VARIABLE LENGTH CODING TABLE
33.2
P TH VARIABLE LENGTH CODING TABLE
33.P
31
ZIGZAG SCANNER
QUANTIZED DCT COEFFICIENTS

FIG. 6B

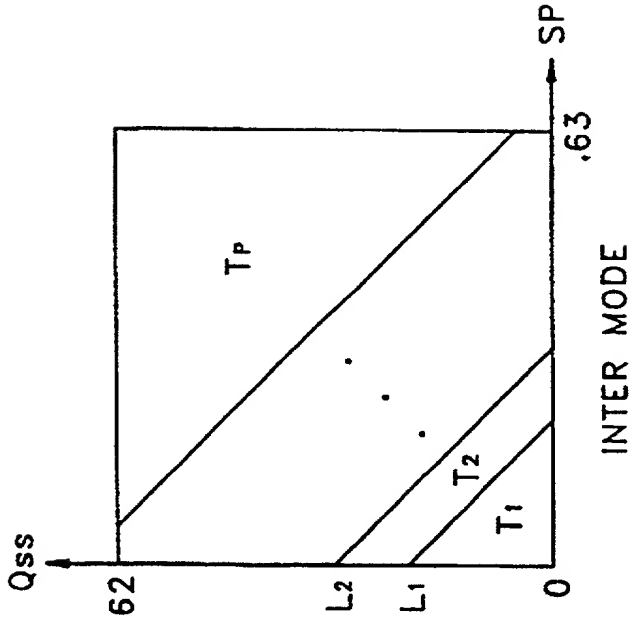

SP
63
Tp
T2
T1
Qss
62
L2
L1
0
INTER MODE

FIG. 6A

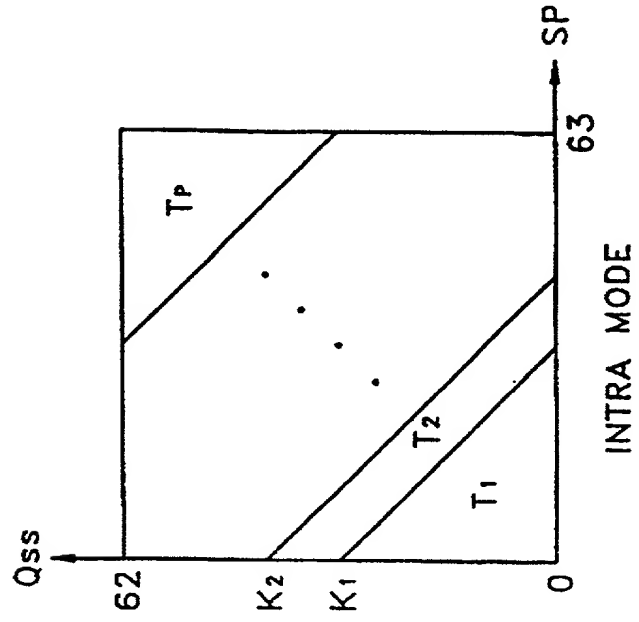
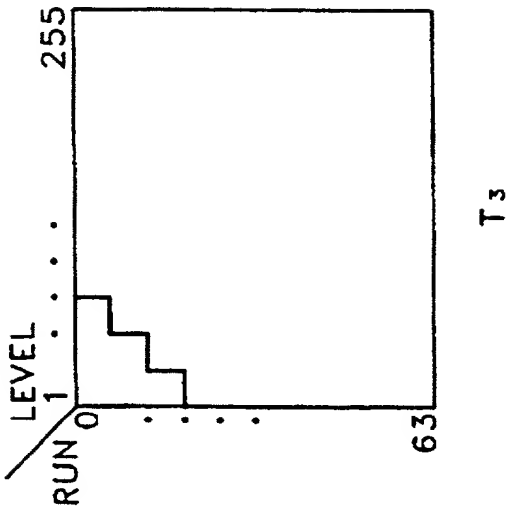
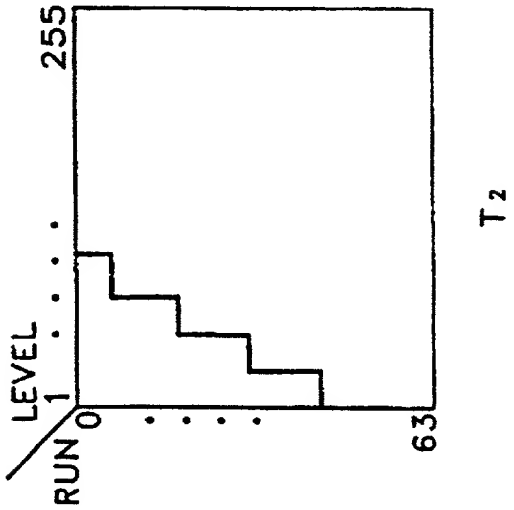

SP
63
Tp
T2
T1
Qss
62
K2
K1
0
INTRA MODE

FIG. 7C



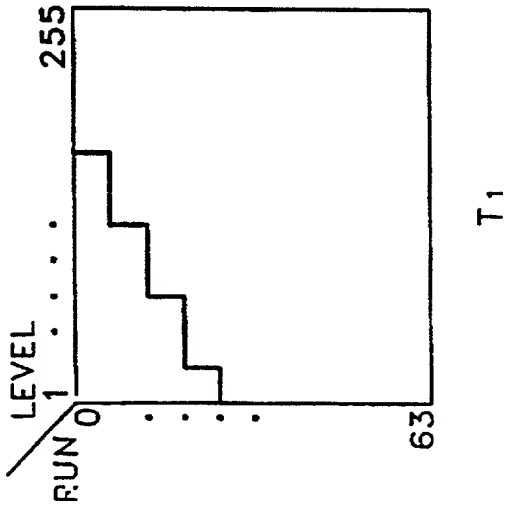
T_3

FIG. 7B



T_2

FIG. 7A



T_1